



## UNITED STATES AIR FORCE RESEARCH LABORATORY

### DIMENSIONALITY OF ABILITY-REQUIREMENTS FOR GENERIC JOB ACTIVITIES

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13. ABSTRACT (Maximum 200 words)  This study presents partial results from an ongoing research effort which is investigating the linkages between taxonomies of work and human abilities. Results are presented from a cross-system comparison of the dimensions underlying ability-requirement matrices derived from three structured job analysis questionnaires and three sets of cognitive, physical, psychomotor, and sensory abilities. Exploratory factor analyses were conducted on the intercorrelations of mean ability-requirement ratings of nomothetic job elements. The Analyses produced a core set of human performance factors that were meaningful, replicable and similar between the three independent samples. Such factors might prove useful in condensing and organizing ability-requirements information and in comparing results across instruments. In some instances, they might serve as stable composite variables for such purposes as job ability-requirement estimation and job evaluation.				
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## DIMENSIONALITY OF ABILITY-REQUIREMENTS FOR GENERIC JOB ELEMENTS

Psychologists have long sought dimensions which define and explain behavior as it relates to the worlds of work and human abilities (Cunningham, Tuttle, Floyd, & Bates, 1974; Drewes, 1993; Dunnette, 1976). Several research programs have been directed toward establishing dimensions of human work and human abilities. Although classification efforts in these two domains have produced promising results, they have proceeded largely independently. The result has been two differing taxonomic thrusts which have implications in the area of human performance. Several authors have called for research which explores the linkages between these two taxonomic worlds. In the present research, the job component approach proposed by McCormick (1979) was used to investigate these linkages.

The job component approach involves (a) the development of a general, universal set of job elements (components) and (b) the establishment of ability-requirement weights for those job components. The weights, which can be established using subject matter experts, represent the extent to which the abilities are required for successful performance relative to the job components. Subsequently, these ability-requirement estimates can be derived for any job that is rated or scored on the job components (e.g., Cunningham et al; 1983; McCormick, DeNisi, & Shaw, 1979; Sparrow, 1989). For research purposes, these estimates can provide a basis for investigating the linkages between the taxonomic worlds of work and human abilities (Peterson and Bownas, 1982).

The present study explored linkages between work and human ability taxonomies by investigating the dimensionality of ability-requirement matrices derived from three sets of

general job elements. For that purpose, exploratory factor analysis was regarded as an appropriate analytical tool. The hypothesis was that a given ability-requirement matrix, derived for a set of general work descriptors and a set of defined human abilities, could be reduced to a smaller set of meaningful human performance dimensions. To investigate this hypothesis in a way that would provide evidence for the convergent validity of the results, we analyzed three independently developed matrices.

## METHOD

### Instruments and Raters

The study involved three structured job analysis questionnaires and three sets of defined human abilities. The job analysis questionnaires included the General Work Inventory (GWI; Cunningham, Wimpee, & Ballentine, 1990), the Occupation Analysis Inventory (OAI; Cunningham, Boese, Neeb, Pass, 1983), and the Position Analysis Questionnaire (PAQ; McCormick, Jeanneret, & Mecham, 1972). Each of 217 GWI job elements was rated by job analysts, personnel specialists, and/or graduate students on 54 ability definitions in the Manual for Ability Requirement Scales (MARS; Fleishman, 1975, 1990; Fleishman & Quaintance, 1984). Each of 545 OAI job elements was rated on 36 ability definitions in the Attribute Requirement Inventory (ARI; Neeb, Cunningham, & Tuttle, 1970; Cunningham, et al, 1983). Each of 182 PAQ job elements was rated on 49 ability definitions compiled by McCormick and his associates (Mecham, 1968; Marquardt & McCormick, 1972).

### Procedures

A job element's estimated requirement for a particular ability was derived by computing a mean from several judges' ratings. This produced from each of the three rating sets a job element-by-ability matrix of ability-requirement weights. The ability-requirement matrix for the GWI data is represented in Figure 1.

		<u>Human Attributes</u>					
		<u>1</u>	<u>2</u>	<u>3</u>	.	.	<u>k</u>
<u>Job</u>	<u>1</u>	$W_{11}$	$W_{12}$	$W_{13}$	.	.	$W_{1k}$
	<u>2</u>	$W_{21}$	$W_{22}$	$W_{23}$	.	.	$W_{2k}$
	<u>3</u>	$W_{31}$	$W_{32}$	$W_{33}$	.	.	$W_{3k}$
	<u>q</u>	$W_{q1}$	$W_{q2}$	$W_{q3}$	.	.	$W_{qk}$
<u>Components</u>		.	.	.	.	.	.
		.	.	.	.	.	.
		.	.	.	.	.	.

Figure 1. Requirement weights of q job components on k human attributes.

Reliability estimates for the ratings were determined by an analysis of variance (ANOVA) procedure for estimating inter-judge agreement (Winer, 1971). A repeated-measures ANOVA

procedure was performed separately for each of the abilities, with raters as the treatment variable and the job element items as the cases on which repeated measures were taken. Using this procedure, an inter-class coefficient of reliability was computed for each ability. The inter-class coefficient can be interpreted as an estimated correlation between the mean ability-requirement rating profile of the job elements and a hypothetical mean profile derived from a new sample of raters drawn randomly from the same population.

Separate factor analyses were performed on complete GWI, OAI and PAQ ability requirement matrices. All abilities within each matrix were inter-correlated based on their job element weights (217 GWI job elements, 545 OAI job elements and 182 PAQ job elements), and the resultant correlations were subjected to principal axes factor analysis using R-squares as communality estimates, followed by varimax rotation. In order to determine the number of factors to be rotated the scree test was applied and eigenvalue plots were examined for breaks or discontinuities. Following factor rotation, coefficients of congruence (Gorsuch, 1974) were computed as indices of factor replication between factors that were judgmentally matched between the three solutions. In addition, for the GWI data, the total sample of raters was divided into two comparable subsamples, and subsample data were subjected independently to the previously described analysis. Coefficients of congruence were then computed between factors across subsamples as indices of factor stability.

A second set of analyses involved only matching abilities. That is, the procedure described above was carried out on those abilities which the data sets had in common. Factor interrelationships between data sets were then estimated via coefficients of congruence.

## RESULTS

An estimated reliability was computed for the mean ratings of the job elements on each ability. In general, the ability-requirement ratings showed substantial reliability with more than 90% percent of the abilities across the three data sets obtaining an estimated interrater reliability of .80 or higher. Based on these results it was concluded that the ability-requirement estimates were sufficiently stable for research purposes.

The results from the first set of factor analyses provided a basis for judgmental comparison across the three data sets. Using the previously mentioned criteria 10 factors were rotated in the GWI and OAI analyses and eight factors were rotated in the PAQ analysis. The factor titles and the percent of variance accounted for are listed in Table 1. Table 1 also presents the coefficients of congruence calculated from the GWI subsample analyses.

Six apparent common factors were identified between the three solutions. The titles of these factors were: Strength and Stamina, Equipment-Control Sensory and Motor Abilities, Manual Abilities, Reasoning and Problem Solving, Numerical Abilities, and Visual Field Perception. Two dimensions, Verbal Abilities and Auditory Abilities, emerged from the GWI and OAI data sets, but not from the PAQ data. Four additional factors, though meaningful, were unique to one



solution: Written Comprehension and Closure (from the GWI analysis), Aesthetic Abilities (from the OAI analysis), and Taste-related Abilities (from the PAQ analysis).

The results from the factor analyses on matching abilities provided a basis for empirical comparison between the three solutions. Table 2 presents the factors derived from the GWI and OAI matching abilities. Tables 3 and 4 present the results from the GWI-PAQ and OAI-PAQ analyses.

Table 1. Human Performance Dimensions Derived from GWI, OAI, And PAQ Ability Requirement Data

GWI		% Var.	OAI		% Var.	PAQ		% Var.
			Factor Code and Title					
SS:	Strength and Stamina (.98) <sup>a</sup>	19.73	SS:	Strength and Stamina	8.42	SS:	Strength and Stamina	27.24
EC:	Equipment-Control Sensory and Motor Abilities (.97)	13.70	EC:	Equipment-Control Sensory and Motor Abilities	8.11	EC:	Equipment-Control Sensory and Motor Abilities	3.76
Mn:	Manual Abilities (.95)	10.10	Mn:	Manual Abilities	10.98	Mn:	Manual Abilities	5.32
RP:	Reasoning/Problem Solving (.87)	8.23	RP:	Reasoning/Problem Solving	7.81	RP:	Reasoning/Problem Solving	21.78
Nm:	Numerical Abilities (.92)	5.17	Nm:	Numerical Abilities	4.23	Nm:	Numerical Abilities	3.04
VP:	Visual Field Perception (.83)	3.17	VP:	Visual Field Perception	7.17	VP:	Visual Field Perception	17.15
Vb:	Verbal Abilities (.92)	12.32	Vb:	Verbal Abilities	8.68	--		
Ad:	Auditory Abilities (.96)	7.99	SH:	Speech Hearing	3.48	--		
WC:	Written Comprehension	2.66	--		--	--		
Cl:	Closure	2.62	--		--	--		
--			As:	Aesthetic Abilities	3.32	--		
--			BE:	Body Equilibrium	1.88	--		
--			--		--	Mc:	Mechanical Ability	2.23
--			--		--	Ts:	Taste-related Abilities	3.16

<sup>a</sup> The coefficients of congruence were based on GWI sub-sample analyses.

Table 2. Coefficients Of Congruence Between GWI And OAI Based Factors

Factor	SS	EC	RP	Mn	Nm	VP	Vb
SS	<b>.90</b>						
EC	.29	<b>.91</b>					
RP	-.33	-.20	<b>.87</b>				
Mn	.43	.51	-.35	<b>.95</b>			
Nm	-.27	-.19	-.04	.02	<b>.84</b>		
VP	-.02	.09	.10	.21	.10	<b>.87</b>	
Vb	-.40	-.40	.74	-.37	.18	-.22	<b>.85</b>

SS=Strength and Stamina; EC=Equipment Control-Sensory and Motor Abilities; RP=Reasoning/Problem Solving; Mn=Manual Abilities; Nm=Numerical Abilities; VP=Visual Field Perception; Vb=Verbal Abilities.

Table 3. Coefficients Of Congruence Between GWI And PAQ Based Factors

Factor	SS	EC	RP	Mn	Nm	VP
SS	<b>.93</b>					
EC	.61	<b>.76</b>				
RP	-.15	.23	<b>.88</b>			
Mn	.62	.41	-.30	<b>.91</b>		
Nm	-.39	-.21	.40	-.08	<b>.94</b>	
VP	-.01	-.13	-.10	.26	.20	<b>.64</b>
Vb	-.43	-.52	.75	-.37	.22	-.44

SS=Strength and Stamina; EC=Equipment Control-Sensory and Motor Abilities; RP=Reasoning/Problem Solving; Mn=Manual Abilities; Nm=Numerical Abilities; VP=Visual Field Perception; Vb=Verbal Abilities.

Table 4. Coefficients Of Congruence Between OAI And PAQ Based Factors

Factor	SS	EC	RP	Mn	Nm	VP
SS	<b>.87</b>					
EC	.58	<b>.48</b>				
RP	-.18	-.23	<b>.87</b>			
Mn	.60	.20	-.38	<b>.93</b>		
Nm	-.26	-.05	.30	.00	<b>.78</b>	
VP	-.03	-.15	-.02	.16	.23	<b>.74</b>
Vb	-.18	.01	.44	-.13	-.10	-.18

SS=Strength and Stamina; EC=Equipment Control-Sensory and Motor Abilities; RP=Reasoning/Problem Solving; Mn=Manual Abilities; Nm=Numerical Abilities; VP=Visual Field Perception; Vb=Verbal Abilities.

## DISCUSSION

The main purpose of this study was to investigate the factors underlying ability-requirement matrices derived from mean ability ratings of general job elements. The factors that emerged from the overall analyses were meaningful and similar between three independent data sets based on different instruments. This suggests some redundancy in the ratings of job elements on large numbers of abilities. It also suggests the job component approach is a viable approach to investigating the linkages between taxonomies of work and human abilities.

The coefficients of congruence for matched factors on the main diagonals of Tables 2-4 are substantially larger than the off-diagonal coefficients for non-matching dimensions. These

results were obtained using different job analysis instruments and different samples of raters. This evidence suggests that the factors are replicable. As further evidence of factor replicability, coefficients of congruence for GWI sub-sample data (Table 1) were all acceptably large.

Factors such as those derived in this study might prove useful in condensing and organizing ability-requirement information and in comparing results across instruments. In some instances, they might serve as stable composite variables for such purposes as job ability-requirement estimation and job evaluation. Research currently under way will derive factors from jobs' ability-requirement estimates based on job component methodology, and from direct MARS ratings of Air Force enlisted occupations. Future research might apply confirmatory factor analyses to ability-requirement data in order to further support the hypothesized structure.

## REFERENCES

- Cunningham, J. W., Boese, R. R., Neeb, R. W., & Pass, J. J. (1983). Systematically derived work dimensions: Factor analyses of the Occupation Analysis Inventory. Journal of Applied Psychology, 68, 232-252.
- Cunningham, J.W., Tuttle, T.C., Floyd, & Bates, J.A. (1974). The development of the Occupational Analysis Inventory: An "ergometric" approach to an educational problem. JSAS Catalog of Selected Documents in Psychology, 4, (MS No. 803).
- Cunningham, J. W., Wimpee, W. E., & Ballentine, R. D. (1990). Some general dimensions of work among U.S. Air Force enlisted occupations. Military Psychology, 2, 33-45.
- Drewes, D.W. (1993). The Role of General Work Activities in the DOT Review. Prepared for the DOT Review Initiative, U.S. Department of Labor. Raleigh, NC: Conserva.
- Dunnette, M.D. (1976). Aptitudes, abilities, and skills. In M.D. Dunnette (Ed.), Handbook of industrial and organizational psychology. Chicago: Rand McNally.
- Fleishman, E. A. (1975, 1990). Manual for Ability Requirement Scales (MARS): Form A (Revised). Fairfax, VA: Author.
- Fleishman, E. A., & Quaintance, M. K. (1984). Taxonomies of human performance: The description of human tasks. Orlando, FL: Academic Press.
- Gorsuch, R.L. (1974). Factor Analysis. Philadelphia: Saunders.
- Marquardt, L.D. & McCormick, E.J. (1972). Attribute Ratings and Profiles of the Job Elements of the Position Analysis Questionnaire (PAQ). Occupational Research Center, Purdue University. (Prepared for Office of Naval Research under contract No. N00014-67-A-0226-0016., Report No. 8).
- Mecham, R.C. (1968). Ratings of attribute requirements of job elements in a structured job analysis format. West Lafayette, IN. Unpublished M.S. thesis, Purdue University.
- McCormick, E.J. (1979). Job analysis: Methods and applications. New York: AMACOM.
- McCormick, E.J., DeNisi, A.S., & Shaw, J.B. (1979). Use of the Position Analysis Questionnaire for establishing the job component validity of tests. Journal of Applied Psychology, 64 (1), 51-56.

McCormick, E. J., Jeanneret, P. R., & Mecham, R. C. (1972). A study of job characteristics and job dimensions as based on the Position Analysis Questionnaire (PAQ). Journal of Applied Psychology, 56, 347-368.

Neeb, R. W., Cunningham, J. W., & Tuttle, T. C. (1970). The Attribute Requirement Inventory. Raleigh, NC: Center for Occupational Education, North Carolina State University.

Peterson, N.G. & Bownas, D.A. (1982). Skill, task structure, and performance acquisition. In M.D. Dunnette and E.A. Fleishman (Eds.) Human performance and productivity: Human capability assessment. Hillsdale, NJ: Lawrence Erlbaum.

Sparrow, J.J. (1989). The utility of PAQ in relating job behaviors to traits. Journal of Occupational Psychology, 62, 151-162.

Winer, B.J. (1971). Statistical procedures in experimental design. New York: McGraw-Hill.

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